

THE DOMESTIC AND GLOBAL ENERGY
OUTLOOK FROM THE PERSPECTIVE OF
THE INTERNATIONAL ENERGY AGENCY

HEARING
BEFORE THE
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
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THE DOMESTIC AND GLOBAL ENERGY OUTLOOK FROM THE PERSPECTIVE OF THE INTERNATIONAL ENERGY AGENCY

TUESDAY, JANUARY 16, 2018

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Committee met, pursuant to notice, at 10:10 a.m. in Room SD-366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning, everyone. The Committee will come to order as we begin our first hearing in what promises to be a very busy 2018.

I would like to provide specific welcome this morning to our new member, Senator Smith. It is good to have you as part of the Committee. I think you will find that this is a committee that does good work. We like to focus on policy, and we like to do things in a bipartisan way every now and again. I am looking forward to starting the new year off on that good foot.

We do not have Senator Capito with us this morning, but she is also returning to our Committee, and I look forward to welcoming her and her ongoing contributions.

We do have a lot on our agenda today. Our broad bipartisan Energy and Natural Resources bill, again, we are looking forward to continuing that as the year progresses, as well as our efforts to increase our nation's mineral security, our need for a wildfire funding fix paired with forestry management reforms, park maintenance backlog, energy innovation, electric reliability, islands and territories. We have a wide range of public lands legislation. Those are just a few of the things that we have on deck for this new year.

We are probably going to have a lighter attendance this morning. I think many members are still returning to Washington ahead of this evening's vote. But I truly thank you, Dr. Birol, for your attendance this morning.

I think, as I mentioned to you, we look to the International Energy Agency (IEA) for its guidance, for its forecast, for better understanding of what is happening around the world. And so, you being here this morning to help set the stage for the year and provide your agency's perspective on the domestic and global energy outlook is greatly, greatly appreciated.

The good work done by the IEA helps to identify market trends and provides valuable information to guide policy decisions, both here in the United States and around the world. IEA's insight and analysis helps us move our policies in the right direction. In turn, our work helps the IEA with its core mission—promoting energy security, cooperation, and stable markets.

We cannot emphasize too strongly how significantly the role of the United States has evolved in recent years. As Dr. Birol notes in his prepared statement, "The United States has become the undisputed global oil and gas leader."

During my time here on the Committee, both as Ranking Member and as Chair, we have gone from discussing the needs to site LNG import terminals all along our coasts to now expediting LNG export terminals. And we have gone from lamenting our reliance on foreign oil and the steep price of that oil, to the United States being the world's swing producer in an era of abundant energy.

Technology innovation and the shale revolution have led the way and the Administration is working hard to reduce barriers to energy development. Allowing for increased exploration and production in the United States, as we did at the end of last year with the opening of Alaska's 1002 Area, will provide for our long-term security and allow us to extend our influence in world markets.

At the same time, we know that these markets are cyclical and that prices could rise substantially in the future if we do not take proactive steps to spur investment and supply. Just last March, the IEA warned that global oil supply could lag after 2020 if new investments are not made in the near-term. That is a warning for all of us. I know the IEA has continued to conduct significant research on this matter and I look forward to delving a little bit deeper into that this morning.

Although the IEA was established on the premise of cooperative oil security, the agency has also evolved and expanded its mission to cover a wide range of energy-related topics. These include energy efficiency, the digitalization of energy, and one that I am particularly interested in and that is the cost reduction in renewable technologies which portend major shifts in how we generate and use energy.

Our Committee has examined these topics largely through a domestic lens. So today we have the benefit, again, of an international perspective, a broader view that ties together world trends and events. We certainly look forward to it.

Again, Dr. Birol, thank you for taking time this morning to come and testify. We know that your schedule is very, very busy when you travel from Paris and we appreciate your willingness to share your expertise and the work of the IEA with our Committee.

With that, I turn to Senator Cantwell for her opening comments.

**STATEMENT OF HON. MARIA CANTWELL,
U.S. SENATOR FROM WASHINGTON**

Senator CANTWELL. Thank you, Madam Chair and thank you for scheduling today's hearing, although, I think I did suggest at one point in time we visit Dr. Birol instead.

The CHAIRMAN. Yes, we will work on that.

Senator CANTWELL. But we were not able to do that.

But I so appreciate him being here today and for the discussion on the IEA's primary focus on increasing energy security for its member nations and I appreciate its continued focus on expanding the definition of energy security as well because energy security means more than just oil and gas flowing in and out and across borders.

It also means protecting critical infrastructure from both physical attacks and the cybersecurity attacks that have been much the subject of a lot of the past Administration's focus on the Quadrennial Energy Review and what we need to do to upgrade that and upgrade the security of our nation. We must take action to protect our critical infrastructure from cybersecurity attacks and ensure the security of energy. Our grid and energy networks are under constant cyberattack. From 2012 to 2016 reported cyber incidents against U.S. critical infrastructure more than doubled.

Now that our vulnerabilities have been exposed by various attempts, including Russians, to hack into our electricity grid, the cyber threat is no longer just a threat. We have been hacked and we must take additional steps to protect our energy infrastructure.

I very much appreciate the Chair, last year, traveling to the Pacific Northwest to see some of the latest and greatest, both technologies and approaches to cybersecurity. She and I have worked on legislation that we passed out of the United States Senate. We are just hopeful that sometime our colleagues in the House will make this a priority and move forward on working on a bicameral basis on cybersecurity since its infrastructure is so important.

Obviously, diversifying our energy mix is another key part of the energy security puzzle and security means minimizing the potential consequences of climate impact which threatens our well-being at home and around the world as well. Investing in renewable energies and moving away from fossil fuels and moving into energy efficiency and ways to help drive down costs—we have seen great examples of the fact that the energy savings from energy efficiency is a continuous flow of investment into business that makes them even more competitive which then allows them to stay ahead on a competitive basis.

So those numbers on energy efficiency, as we look at everything from the Bullitt Foundation building to a focus on how to make more of these developments worldwide—very, very exciting technology that we are very proud of from the Pacific Northwest.

According to the IEA's World Energy Outlook, renewable energy will make up two-thirds of the global investment in electricity as they become the cheapest sources in new generation. The IEA finds that the costs of new solar PV have come down 70 percent, wind by 25 percent and battery costs by 40 percent.

Energy efficiency, as I just mentioned, is also a key on the energy security side. The total energy use would have more than doubled, according to IEA, without energy efficiency. So this has been saving us in so many ways. As you noted, I think it is one-third the cost to save a kilowatt than to develop it. It is so important that we continue that.

While we are discussing so-called energy dominance and energy security, I hope we will hear a lot less about just these exporting issues. Although, again, we worked hard here on the Committee to

come up with strategies that clarify what our national policies were on that and focus on what we can do to drive the cost of energy. Whoever has the most cost-effective energy solutions is going to continue to win in the marketplace.

I look forward to hearing your comments on that today. And again, thank you for being here.

The CHAIRMAN. Thank you, Senator Cantwell.

Dr. Birol, welcome, again, to the Committee.

For those who are not familiar with Dr. Birol, he took office as IEA Executive Director in September 2015 after 20 years with the agency itself. Previously, Dr. Birol held the position of Chief Economist with responsibility for directing the flagship World Energy Outlook publication. He has been the founder and the Chair of the IEA Energy Business Council. He has a whole series of accolades and awards that have been conferred upon him over the years.

Again, Dr. Birol, we appreciate the insight that you will provide for us and the good work of your team at the International Energy Agency. We welcome you, and we invite your comments this morning.

Typically we ask those who are testifying before the Committee to try to limit their comments to five minutes, but because you are the sole panelist before us, I welcome your extended remarks and then we will have an opportunity to query you with regards to other issues.

Thank you and good morning.

**STATEMENT OF DR. FATIH BIROL, EXECUTIVE DIRECTOR,
INTERNATIONAL ENERGY AGENCY**

Dr. BIROL. Madam Chair, Ranking Member Cantwell, distinguished members of the Committee, thank you very much for the opportunity to appear before you today and present the International Energy Agency's outlook for global energy markets.

Let me also join Madam Chair to wish everybody a Happy New Year.

For the International Energy Agency, 2017 was a very successful year, a year of growth and continued success. One of the highlights of our successful year, 2017, was that in November our ministers across the world came together to do a bit of business and to discuss the global energy issues, challenges, how they see the challenges in different countries and to provide guidance to International Energy Agency. And I would like to, here, thank the U.S. Government, especially Secretary Perry, for his personal engagement to our Ministerial meeting.

There were also several businesses joining our meeting, at least part of it. Several CEOs from the United States joined us, CEO of Exxon Mobil, CEO of General Electric, CEO of Dow Chemicals and also other CEOs, Shell, Total Energy, renewable companies across the world. We had a wonderful ministerial meeting with a very good discussion and I would like to reflect some of the discussions to you today.

Before going to some of our thoughts and findings, I would like to, just very briefly, Madam Chair, if I may, tell you what the IEA is all about. We were founded in 1974 in the wake of an oil crisis, basically by Mr. Henry Kissinger, himself and several other states-

men across the world, and we are now 43 years old. The motivation of the IEA was oil security, to look after the oil security issues, providing an oil security mechanism across the world. But throughout these years our mandate has evolved, as Madam Chair mentioned. We look at the oil, gas, renewables and energy efficiency and alignment issues and investments and we look at all the technologies. IEA is a unique organization which looks at all the technologies and their implications for the markets and our well-being.

We have several member governments in all the continents and energy, Madam Chair, is a very hot topic in many governments, in many countries. So we try to bring some factual information for the governments, for the decision-makers, to discuss, to debate and come up with, hopefully, good solutions for the countries and for their citizens.

Now, to provide a basis for our discussion, I would like to tell you how we see the global energy markets in the next years to come, and I will highlight four major trends which will affect all of us. I would like to say that countries—even the United States, one of the most important energy countries in the world—even the United States is not an energy island. What happens in other countries affects all of us and what happens in the United States, as I will show in a minute, will affect everybody else.

So, therefore, these four major trends, or pillars we call them, will affect all of us in the next years to come given the size of these changes and also the speed of those changes I think it is important for all of us to take note of them. What are these four major upheavals which are going to transform our energy markets and some of the definitions, discussion, we used to know, but perhaps we need to change now?

Number one, Madam Chair mentioned, the United States is set to become the undisputed leader of oil and gas production for many years to come with huge implications. This is number one.

Number two, the cost of renewable energies is going down so significantly that they are becoming the first choice of new power plants in several countries across the world. And these choices are not necessarily driven by the environmental concerns only, but only for the cost concerns because they are becoming very cheap. When I say renewables, this is mainly solar and wind. This is number two.

Number three, China. China recently changed its economic policy, namely moving from being an industrial workshop, workhouse, manufacturer, slowly but surely, to a lighter economy and with the new motto, “making the skies of China blue again,” China is moving in the direction of clean energy, which will have major implications for all of us given the sheer size of the Chinese energy markets. When I say clean energy, this is gas, renewables, nuclear power and others.

Fourth, and the last, upheaval is that within the energy system, we use energy, the share of electricity is growing very strongly. Electricity consumption is growing much faster than oil and gas and coal, everything else, and our lives, our social lives, our economic lives, are becoming much more connected and electricity has a critical role.

So, these are the four major upheavals that we see as very important. If I can elaborate on them a bit. I'll put you in the U.S., perhaps the most important one to the end of these four important upheavals starting with the clean energy technologies.

As Senator Cantwell mentioned, the cost of solar PV fell down substantially. In the beginning, several countries, especially European countries, subsidized the solar. But now, after emerging countries, especially China, pushed the solar PV and there is a concept in the economy, learning by doing. The more you do something, the better you do it and the cheaper you do it and the cost of solar is now going to very, very low levels.

The second, wind. The cost of wind is also going to go down. It's going down and in addition to the industrial countries, major growth of renewables is coming from today, emerging countries, especially China and India are the leaders. China is, today, the number one country in terms of solar and number one country in terms of wind, worldwide.

And when we look at the future we see that the cost of solar and wind continue to decline and they are going to compete very soon, without the subsidies and competing with the traditional sources of electricity. This is something important and why China and others are pushing solar. It is not necessarily, as some people may think, for a primary reason is not climate change. The primary reason is because it is cheap and the second is that another environmental issue, especially in China and in India is the city—local pollution in the cities. To reduce the local pollution, those countries are pushing solar and wind substantially and they are becoming cheaper and cheaper.

We are seeing a big growth of solar and wind in the next years to come. And if I can give you one number—the forecast, only in 2016, of the old power plants built in the world, solar alone was more than 50 percent—solar; other 50 percent—other renewables, plus coal, plus oil, plus gas, plus nuclear put together, 50 percent. The other 50 percent, solar capacity alone. So this is something that we need to take into consideration.

I should also mention that the renewables, especially solar and wind, also has a shortcoming—namely, they are very much bound to the weather conditions. In India, when the family comes home in the evening from work, the first thing they do is turn on the air conditioner, turn on the television, when there is no sun, when the sun sets. So it is difficult to, it is not very easy I should say, to match when there is sun and when the electricity market is very high. And there are some technologies that we are working, and others are working on that. But to sum up, clean energy technologies are coming and coming strongly and cheaper.

Another point is on electricity. As I said, electricity is going very strongly everywhere. The electricity consumption grows two times faster than the overall energy consumption. As our lives are becoming more and more of the electrical advances, industrial processes are becoming more and more electrified and the cooling needs, air conditioners, are becoming a major driver across the world.

This is important to note and, therefore, what kind of power plants we're going to build is a key question and at the same time since electricity will be more used, will be more dominant in our

social and economic lives, the electricity security becomes a critical issue.

In the case of electricity supply disruption, our entire economic, social life and the communication processes will be paralyzed. So therefore, it is an area that the International Energy Agency is working on, the issue of electricity security.

Third, China. Third upheaval. China is, today, the largest energy consumer of the world by far, and last year at the Chinese Communist Party Congress, President Xi said, “we want to make the skies of China blue again.” Once again pushing the Chinese energy prospect into cleaner direction—lots of support for renewable energies, lots of support for energy efficiency, lots of support for natural gas and electric vehicles.

China is, today, in terms of coal markets, to give the size—half of the coal in the world is used in China; the other half, everybody else put together. And China, today, is putting a cap on the coal consumption in order to limit the pollution in the cities, basically.

And China is, with the new policy, replacing coal with renewables, but also with natural gas. And if I may come back to what I said in the beginning, that no country is an energy island. China is poised to going from coal to gas in a very short period of time and it is a major LNG imports of China. And it is out of that, within one year of time, the LNG process in Asia Pacific jumped from \$6.00 to \$11.00, almost double, because of China’s new policy. So this will affect everybody, exporters and others. China is going to be the largest oil consumer very soon, overtaking the United States.

Another area which I would like to bring to your attention is the nuclear power and China. China, today, is the country which is the most engaged with the nuclear power industry, and we see that more than one third of all nuclear power plants under construction today will be in China. And looking at what’s happening in the United States, our numbers show that in 10 years of time Chinese nuclear capacity will overtake the United States, and China will be number one and the United States will be number two in terms of nuclear capacity, if the current policies do not change.

But, in general, China’s policies are changing. Ten years ago, we may remember as a result of the Chinese boom, there was an impact on the oil markets, coal markets, emissions. Now another China and other policies on clean energy, electric energy, and this will also affect the energy markets.

My final point, Madam Chair, is about the United States—the fourth and perhaps another critical, as we call it, big-time nation of the energy markets. What we say is that as a result of the shale revolution, the U.S. is becoming the undisputed leader of oil and gas production worldwide.

In terms of oil, oil production is going very strongly and will continue to grow. All of our expectations are in that direction and we think that this growth is unprecedented—the size of the growth and the pace of the growth. We have seen such a big growth in the history of oil only once when in the four and a half decades ago Saudi Arabia expanded their very famous Ghawar oil field. It’s the biggest oil field in the world.

In terms of natural gas, the United States, again, is out of shale gas increasing its production strongly and going to bring a lot of LNG to the markets. And we expect the U.S. will be the largest LNG exporter of the world in the year 2020.

Both of these developments have implications for the prices, for energy security worldwide, trade, investments and, of course, for the U.S. economy. This is definitely good news for the U.S. economy, both in the developments on the gas and the oil side. And our projections show that this leadership of the United States, in terms of oil and gas, will continue for many years to come, especially if it is combined with the right domestic policies at home.

So these are the four major upheavals we see, Madam Chair, namely the cost of renewables are going down substantially and they will be a mainstream fuel. They have been considered as a “romantic fuel” in the past and they are not anymore, so they are mainstream fuel now. Second, we see that electricity is becoming a very important fuel in our society now, in our economic lives, in our social lives with a lot of efficiency gains, but also bring a lot of challenges, especially in the context of the electricity security picture. Third, China is changing up its energy policies going from a coal-based, heavy industry economy slowly but surely to clean energy technologies and making more and more use of natural gas. And fourth, perhaps the most important, the United States is becoming the undisputed leader of oil and gas for the years to come.

So I would like to finish my words, Madam Chair, that the International Energy Agency is following the developments in the United States and across the world. We are talking with all the governments around the world, and we are trying to bring the best advice based on effects, analysis and data. And we are, today and anytime, at your disposal to answer your questions and requests.

Thank you very much.

[The prepared statement of Dr. Birol follows:]

Dr Fatih Birol, Executive Director, International Energy Agency

**Written testimony
Hearing of the U.S. Senate Energy and Natural Resources Committee**

**Dr Fatih Birol
Executive Director
International Energy Agency**

January 16, 2018

Chairman Murkowski, Ranking Member Cantwell, and distinguished Members of the Committee, thank you for the opportunity to appear before you today and to present the International Energy Agency's outlook for global energy markets.

It has been my privilege to serve as the Executive Director of the International Energy Agency (IEA) for slightly more than two years now. And it is my distinct pleasure to share with you our very latest market outlook.

Let me start by wishing you all a Happy New Year. For the IEA, 2017 was a year of growth and continued transformation. In particular, our Ministerial Meeting held last November was a remarkable success, in no small part thanks to contributions made by the U.S. I would like to particularly thank Secretary of Energy Rick Perry for his personal engagement, including for co-chairing a Carbon Capture, Utilization and Storage Summit on the side-lines of the Ministerial, which included the participation of many other ministers and CEOs of some of the world's leading energy companies.

A brief overview of the IEA

The strong relationship between the United States and the International Energy Agency goes back to the founding of the IEA in 1974. Throughout these more than 40 years, the United States has played an absolutely critical leadership role in the IEA. And, U.S. leadership and support has not only come from the Executive Branch, including the White House, Department of State and Department of Energy, but also very much from this Committee and from the Congress more generally.

I know that you, Madam Chair, and many of your colleagues know very well what the IEA does, but I also appreciate that not everyone here will be fully familiar with the exciting recent developments at your IEA.

The IEA was founded by United States and 16 other countries in the wake of the 1974 oil crisis to promote energy security, cooperation and stable markets. As the world has evolved, so has the IEA. While energy security remains a core part of our mandate, the IEA has also grown to become the world's leading energy-policy advisor across the entire energy mix, providing data, analysis and solutions to governments and industry on all fuels and technologies.

During our 2017 Ministerial Meeting, our members reaffirmed your commitment to the IEA's modernization strategy, which is based on three pillars.

The first is opening the IEA's doors to emerging economies. Over the last two years, we have welcomed seven new IEA Association members – China, India, Brazil, Indonesia, Thailand, Morocco and Singapore – reflecting more accurately the global nature of the energy system.

Our Association countries are now developing closer relations with the Agency, participating in meetings of IEA committees and standing groups, working with us closely on improving energy data and statistics, strengthening energy security relationships, undertaking energy policy studies, and cooperating more closely with the Agency on their energy policies. We have also recently welcomed Mexico as our newest member. As a result, our expanded IEA family is now much more global, accounting for 70% of the world's energy use, up from under 40% in 2015.

The second pillar of our modernization agenda is to deepen our focus on energy security. This means expanding our scope beyond the traditional focus on oil security to new issues affecting the security of natural gas markets as well as electricity supply. This is reflected in our recent work to understand the implications for gas security of a more globalized liquefied natural gas (LNG) market, as well as our pioneering work on the integration of larger shares of variable renewable generation into electricity systems.

The third modernization pillar is to strengthen the IEA's role as a leader in clean energy, including building a global hub for energy efficiency. Specifically, we help our Members to cost-effectively achieve their own clean energy objectives, which can include renewables and efficiency, as well as carbon capture, utilization and storage (CCUS) and nuclear power. One key aspect of this approach is our work with around 40 IEA Technology Collaboration Programs (TCPs), which are made up of 6,000 research analysts from around the world. The United States is represented in almost all of these TCPs – more than any other country – across a range of sectors and technologies from transport and electricity, to fossil fuels, renewables and other clean energy technologies.

These three pillars represent the future of the IEA as a truly global energy institution covering the full range of the energy mix.

Looking over the horizon

In my last written testimony to this Committee, I focused on energy security, recent developments in oil, gas and renewables, and the medium-term outlook for the range of fuels covered by the IEA. Today, I would like to take the opportunity to look further ahead, and focus on the forward looking scenarios that define the IEA's flagship publication – the *World Energy Outlook*.

While we produce a range of scenarios, I will focus on the outlook in our central scenario, which describes where existing policies and announced intentions might lead the energy system by 2040. We produce this scenario to inform decision-makers about the impact of their existing and planned policies as they seek to improve on this outcome.

Four large-scale shifts in the global energy system set the scene for the coming decades: 1) the U.S. becoming the undisputed global oil and gas leader; 2) the rapid deployment and falling costs of clean-energy technologies; 3) the shift to a more services-oriented economy and a cleaner energy mix in China; and 4) the growing electrification of energy.

With regard to the rapid deployment of **clean-energy technologies**, in 2016 the growth in solar photovoltaics (PV) capacity was larger than for any other form of generation. Since 2010, costs of new solar PV have fallen by 70%, while wind costs have dropped by 25% and battery costs by 40%. This trend is set to continue, signalling the coming new age of renewables.

Under our central scenario, renewables capture two-thirds of global investment in power plants to 2040 as they become, for many countries, the least-cost source of new generation. Rapid deployment of solar PV, led by China, India and the United States, helps solar become the largest source of low-carbon capacity by 2040. In the European Union, renewables account for 80% of all new capacity and wind power becomes the leading source of electricity generation. By 2040, the share of all renewables in global total power generation reaches 40%.

In the United States after 2020, use of renewables-based electricity grows faster than the use of renewables for heat and transport combined. However, in our central scenario, the annual rate of growth of renewables in the United States slows from 3.5% per year to 2.5% per year after 2025.

Policies are still needed to support the deployment of renewable electricity worldwide, increasingly through competitive auctions rather than feed-in tariffs and by ensuring that power systems operate with sufficient flexibility to accommodate rising shares of solar and wind power. The transformation of the power sector is amplified by millions of households, communities and businesses investing directly in distributed solar PV.

Of course, clean-energy technologies include far more than renewables. In particular, energy efficiency will be key to reducing demand across all sectors. Energy efficiency is central to the achievement of a range of policy goals, including energy security, economic growth and environmental sustainability.

The progress on energy efficiency over the past few years has been remarkable, with global energy intensity – measured as the amount of primary energy demand needed to produce one unit of gross domestic product (GDP) – declining at an average rate of 2.1% per year. This is a significant improvement over the average rate of 1.3% between 1970 and 2010. Lower energy intensity was responsible for offsetting three-quarters of the increase in greenhouse gas (GHG) emissions due to GDP growth, with the shift to renewables and other low-emission fuels offsetting the other quarter.

However, in contrast with previous years, nearly all the increase in 2016 in the share of world final energy use covered by policies that mandate energy efficiency improvements was due to the continuing impact of existing policies, as old energy-using equipment was replaced. Just 1% of the increase was due to newly enacted policies – marking an historic low that deserves specific attention from policy makers.

Stronger policy development and implementation is essential if the current level of efficiency gains is to be maintained or accelerated over the coming decades. In our central scenario, improvements in efficiency play a huge role in taking the strain off the supply side to 2040. Without these improvements, the projected rise in final energy use would more than double. If the world's policy ambitions are to be met, governments must recognise the importance of developing and putting into force new and more ambitious efficiency policies.

The second major theme, which is very much related to the growth in clean-energy technologies, is how **electricity** will play a rapidly expanding role in the energy sector.

Electricity is the rising force among worldwide end-uses of energy, making up 40% of the rise in final consumption to 2040. This is the same share of growth that oil took for the last 25 years. Global rising incomes mean that many millions of households add electrical appliances and install cooling systems. With total electricity demand growing at 2% per year from 2016 to 2040 – nearly twice the rate of final energy

demand – electricity experiences more growth than all other fuels, meeting over 37% of additional final energy demand.

Electricity also makes inroads in supplying heat and mobility, allowing its share of final consumption to rise to nearly a quarter. A strengthening tide of industry initiatives and policy support pushes our projection for the global electric car fleet up to 280 million by 2040, from 2 million today.

The scale of future electricity needs and the challenge of decarbonising power supply help to explain why global investment in electricity overtook that of oil and gas for the first time in 2016 and why electricity security is moving firmly up the policy agenda.

This does not come without significant challenges. For example, because wind and solar PV are variable renewable resources and their input cannot be fully forecast and programmed, the so-called system integration of these variable renewable sources has emerged as a major economic and policy challenge.

The U.S. is not alone in facing this challenge as there are countries with already much larger shares of wind and solar PV in their respective power systems. For example, a number of European countries are dealing with double-digit shares, i.e. up to six times higher than the U.S., demonstrating that integrating high shares of wind and solar in a reliable and cost-effective manner is possible, provided that power systems become flexible enough.

The U.S. already boasts a number of power system flexibility resources, including more flexible thermal power plants (mainly gas, but possibly also coal), multiple storage options, and demand-side response. In addition to these flexible resources, market design also has a very important role to play in successfully integrating renewables.

Existing and emerging digital technologies will also play a major role in power systems, providing opportunities for not only integrating variable renewables, but also smart demand response, smart charging of electric vehicles, and small-scale distributed electricity resources. However, digitalization of the energy sector can facilitate this positive change only if policy makers undertake efforts to understand, channel and harness digitalization's impacts and to minimise its risks – for example taking steps to ensure our power systems are resilient to cyber-attacks.

Speaking of the third major global trend, the direction that **China** takes over the coming decades will shape all of these trends. President Xi Jinping's call for an "energy revolution", the "fight against pollution" and the transition towards a more services-based economic model is moving the energy sector in a new direction. The emphasis in energy policy is now firmly set on electricity, natural gas and cleaner, high-efficiency and digital technologies.

The scale of China's clean energy deployment, technology exports and investment makes it a key determinant of momentum behind the overall global low-carbon transition: one-third of the world's new wind power and solar PV is installed in China to 2040 in our central scenario, and China also accounts for more than 40% of global investment in electric vehicles (EVs).

China also provides a quarter of the projected rise in global gas demand with projected imports of 280 billion cubic metres (bcm) in 2040. This is second only to those of the European Union, making China a linchpin of global gas trade.

China remains a towering presence in coal markets, but our projections suggest that coal use peaked in 2013 and is set to decline by almost 15% over the period to 2040.

In addition, China overtakes the United States as the largest oil consumer around 2030, and its net imports reach 13 million barrels per day (mb/d) in 2040. But stringent fuel-efficiency measures for cars and trucks, and a shift which sees one-in-four cars being electric by 2040, means that China is no longer the main driving force behind global oil use – demand growth is larger in India post-2025.

In fact, India is the largest contributor to demand growth to 2040 – almost 30% of total growth – as its share of global energy use rises to 11%. Southeast Asia is another rising heavyweight in global energy, with demand growing at twice the pace of China. Overall, developing countries in Asia account for two-thirds of global energy growth, with the rest coming mainly from the Middle East, Africa and Latin America.

The United States: the undisputed global oil and gas leader

Finally, with regard to the fourth major global trend, I would like to speak about the noteworthy resilience of shale gas and tight oil here in the United States, and the future of oil. The remarkable ability of producers to unlock new resources cost-effectively pushes the combined United States oil and gas output in 2040 to a level 50% higher than any other country has ever managed. This is an impressive feat, which cannot be overstated. This makes the United States the undisputed oil and gas producer in the world over the next several decades.

In our projections, the 8 mb/d rise in US tight oil output from 2010 to 2025 would match the highest sustained period of oil output growth by a single country in the history of oil markets. A 630 bcm increase in US shale gas production over the 15 years from 2008 would also comfortably exceed the previous record for gas.

Expansion on this scale is already having wide-ranging impacts within North America, fuelling major investments in petrochemicals and other energy-intensive industries. It is also reordering international trade flows and challenging incumbent suppliers and business models.

By the mid-2020s, the United States also becomes the world's largest liquefied natural gas (LNG) exporter and a few years later a net exporter of oil – assuming increasingly stringent fuel economy standards are enacted. Your country remains a major importer of heavier crudes that suit the configuration of your refineries, but at the same time a larger exporter of light crude and refined products.

As such, with the United States accounting for 80% of the increase in global oil supply to 2025 and maintaining near-term downward pressure on prices, our projections suggest that the world's consumers are not yet ready to say goodbye to the era of oil.

Up until the mid-2020s, oil-demand growth remains robust in our central scenario, but slows markedly thereafter as greater efficiency and fuel switching bring down oil use for passenger vehicles (even though the global car fleet doubles from today to reach 2 billion by 2040).

Yet, demand from other sectors is enough to keep overall oil demand on a modest rising trajectory to 105 mb/d by 2040. Oil use to produce petrochemicals is the largest source of growth, closely followed by rising consumption for trucks, for aviation and for shipping.

However, despite these positive developments, it is worth noting that this central scenario falls short on a range of important goals, namely: universal access to modern energy services and clean cooking facilities, improvements in air quality and the reduction of greenhouse gas emissions. In 2017 the IEA produced, for the first time, a Sustainable Development Scenario as an alternative point of reference in which these objectives are met. It is noteworthy that under this scenario we find that meeting global climate goals does not in fact impede efforts to provide universal access and improve energy security.

Conclusions

The last few years have seen an acceleration in the evolution of the global energy system, with the centers of gravity for both demand and supply shifting dramatically. The United States is a key player in this evolution, and will no doubt continue to help shape the energy system over the coming years.

As we have done over the past 40 years, the IEA looks forward to continue working with all of our partners in the United States and with our other Member Countries, and we stand ready to offer our analysis, advice and support as you oversee your nation's energy policies.

On behalf of everyone at the IEA, I wish to once again thank you for inviting me before your Committee. I am happy to answer any questions.

The CHAIRMAN. Thank you, Dr. Birol.

A great deal to think about here this morning and, again, to understand how the United States has assumed this role, as you say, to be the undisputed leader, certainly when it comes to oil and gas, but recognizing the nature of how we got there and how quickly we have assumed this position.

It is certainly something to consider, but also recognizing what you have shared with us, the role that China is playing and how that, too, will not only impact energy production and consumption around the world but, more specifically, to us here in the United States.

You have mentioned with regards to oil and gas production here in the United States that this is good news for the U.S. economy and for our trade especially, and I am quoting you here, “especially if combined with the right domestic policies.” When you make that statement are you referring to tax policies, are you referring to energy policies? Is it a combination of all of that? If you can go just a little bit more into that I’d be curious.

Dr. BIROL. Of course.

Now the United States is a very fortunate country because you have oil, gas, renewable energy resources and you have a very innovative business here. So by the improvement of the technology you will get more and more oil and gas from the existing resources, if the right incentives are provided to the industry. This is number one. Number two, I believe the U.S. has huge potential to make more use of renewable energies, solar and wind especially, and I was very happy to see that the current support for the renewable energy policies are continuing in a strong way.

The CHAIRMAN. The Production Tax Credits?

Dr. BIROL. Exactly.

Third, there is one concept in the United States which is very important—the independence, energy independence. And that independence is based on two factors: one is increasing the production a lot, domestic production; and second, keeping the consumption at a certain level and not to waste energy, mainly energy efficiency.

So, I think, when I mentioned domestic energy policies, I believe in addition to the supply side policies, production side policies have to increase oil and gas. We must also put emphasis on using energy efficiently so that we don’t waste energy but have the same results and the same productivity from the system.

So all in all I think the U.S. energy system is going in the right direction, a lot of resources, but domestic policies need to help them.

The CHAIRMAN. I appreciate that.

Let me ask you a question specific to the Arctic. I focus a lot in these spaces and not just the U.S. Arctic, but the Arctic broader. Last year I had an opportunity to visit the Melkoya LNG facility in Hammerfest, Norway, where a significant amount of natural gas is processed and shipped to Europe. Of course, over in Russia we are seeing that on the Yamal Peninsula and elsewhere as they are exporting their LNG across the world, including to China.

What role do you see the energy resources from the Arctic, whether it be oil, whether it be gas—and this is not just looking

at the United States but the bigger energy picture—specifically coming from these Arctic northern countries?

Dr. BIROL. Thank you very much.

We have huge deposits of oil and gas in the Arctic region across the world. There are two challenges there. The one challenge is the economic challenge—and then we have a lot of shale oil, whether or not they will be able to get the investors. And second, some of the Arctic resources may pose environmental questions. These are the two issues.

Moving from there, I would put oil and gas differently. In terms of oil, it's actually a huge U.S. Geological Survey. We have huge deposits and if you look at, especially, the ANWR area, the Arctic National Wildlife Refuge Area, we see that there is a very important attractiveness there—namely, the availability of the Trans-Alaska pipeline which is underutilized today substantially. And you have the chances of, if the production was to take place, we have the chances or the possibility of transporting it in a very easy way. This is definitely an advantage.

The challenge, however, is that in terms of oil again the economic attractiveness in the current price and the plan of the shale oil context and therefore, we think that with the current context, it will be difficult to believe that a substantial amount of oil production will be coming from that region before 2030, unless we see some surprises in the markets. Having said that, if significant resources and the production comes from there, this would be good news for the economy and employment in Alaska.

Coming to LNG, it's a different story. The gas in the very region and we know that to unlock the oil we have an issue of the infrastructure here and the main bottleneck, I believe, is the infrastructure—building the pipelines here and the LNG plants—but I see here significant marketing chances, especially for Asia, also given the geographical advantage.

If I may bring it to the point I said a few minutes ago, Madam Chair, today China is moving in the direction of gas. They are going to import a lot of LNG to replace their coal, basically, and I see that there's a lot of opportunity in China and Japan.

I often visit Japan and meet with the Japanese government, Madam Chair. You may well know that they are thankful to you after Fukushima, bringing LNG to the Japanese government when they were in a very, very difficult situation. And as you know, Japanese people, they never forget this good gesture coming from your government.

So, to sum up, I see from an LNG point of view, significant chances to provide gas to a gas-hungry Asian region.

The CHAIRMAN. Very good. Thank you very much.

Senator Cantwell.

Senator CANTWELL. Thank you, Madam Chair.

On that point, I think that the Chair would note that I have, many times, suggested to her that that should be a good focus for Alaska, natural gas, as opposed to the more recent discussion on the ANWR.

As you point out, China being the huge market opportunity for the future poses—with a shift in policy, as you clearly noted, to a bluer sky—being the largest market opportunity for the U.S.

I wanted to ask you about what policies on that clean energy front do you think we need to continue to focus on here that would help us in looking at Asia more as a market for U.S. leadership?

I say that both on the energy efficiency side and the nuclear policy side. Energy efficiency in the context of, I think you have stated well, we are saving so much and we need to continue to move forward. I look at it as everything from the efficiencies that we have achieved within our region to some of the technologies that are now being used in other countries. For example, I think one of our Northwest companies has provided metered energy in South Africa so that they can just buy the power that it takes to turn the lights on when the kids come home from school.

So energy efficiency is making our businesses competitive and it is also reaching the marketplace. What else do we need to be doing to focus on energy efficiency and other export policies on the clean side?

Dr. BIROL. Thank you very much.

Now first of all, the U.S. is becoming an exporter, gas exporter, to China and Asia in general—I mention China but I should have mentioned another country which is very important in the region and growing very strongly, which is India. India is also very important because their economic growth is very strong and they have a very, in my view, wise, sound energy policy. And both of these countries use gas at the minimum level. Globally, their share of gas in the global energy mix is about 25 percent and in both these countries it is less than or around five percent only. So there's a big gap between the world average and them.

And they, both of them, both of these countries are facing major challenges in terms of environment—namely, local pollution in the cities. And this is an issue for, in many countries, both of these countries and others, a reason for social unrest, in fact.

So one solution to that is replacing coal by natural gas and that will get the gas markets—when you see that the U.S. is coming very strongly, in terms of LNG exporter, being an LNG exporter.

And this is good news for everybody, to be honest with you because, I should say almost everybody except for the 12 traditional pipeline exporters in Europe because the U.S. is also providing alternative to Europeans vis-à-vis the major established pipeline exporters and making the hands of Europeans stronger in terms of their negotiations of the price with the pipeline exporters when they make new contracts. Even if they don't import one BCM of U.S. gas, the fact that they can import U.S. gas is a very strong card in their hands.

Coming to China, I think—

Senator CANTWELL. And on that point, could you just elaborate on the Russians as well because aren't they trying to play in this marketplace?

Dr. BIROL. Yes, in fact the Russian government, as a result of the U.S. shale boom. The Russian government is less stronger when it comes to the contract negotiations with the European customers because if the European customers negotiate and try to bring the price down, if the Russians would say no, then there's an option, which is the U.S. gas coming there.

So in the past, in the district there was only one shop in Europe which is Russia. They need to go and buy the gas from that shop. Now, there is another shop open which is the United States. They, the Europeans, can choose which one is cheaper, which one has the better conditions, which one provides better opportunity for the energy and maybe, in some country's cases, the security and foreign policy.

So U.S. gas is providing an alternative to Europeans vis-à-vis the Russian gas. And this is, I think, very important both in terms of energy security, but also the competitiveness of the gas and the contracts in Europe.

It is out of that many European countries really negotiate success with their existing contracts and bring the price of gas down as it is out of the new opportunities coming from the United States and elsewhere.

In terms of China and India, huge opportunity for U.S. gas. It is going to, in the next five years, be a big amount of LNG coming from the United States, and I am sure Asian region will be the primary destination for the U.S. LNG.

And there's a huge opportunity to make money for the U.S. and for those countries to diversify their energy system and make gas part of the energy system and make it much more flexible. And for the Europeans, diversify the source of imports and provide, again, minimizing the economic, social and, maybe, political risks.

Senator CANTWELL. Well, I see my time has expired, but I thank you, Dr. Birol, for elaborating. I think what some people may not fully understand about what the Russian issues are, as it relates to Europe and to us and to why some of these things are so important, people in the Administration and conflicts and everything else.

So I thank you for that.

I wanted to thank my colleague and welcome her to the Committee. I failed to do that in my opening remarks. I am going to turn my portion over to her in the next round and let her continue on my behalf.

Thank you so much for your testimony, and I so appreciate Senator Smith joining our Committee, along with our returning colleague from West Virginia, so it will be great to have her back. This must be a record number of women on the Committee, so that's a good thing.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Cantwell.

Let's go to Senator Cassidy.

Senator CASSIDY. Hey, sir. Thank you. Great testimony. I am intrigued by the electrification of transportation, if you will.

But let me ask you to comment on this. Yesterday, the CEO of Fiat Chrysler was quoted saying, "I don't know of a business that is making money selling electric vehicles, unless selling at a very, very high end of the spectrum." And this was made at the Detroit Auto Show.

How do you, kind of, position that versus your very bullish statement that within a relatively short period of time we are basically going to transition to a primarily, or almost equally, electric car marketplace? Your thoughts?

Dr. BIROL. Thank you very much, Senator.

I think the electric cars, the number of electric cars will grow, but our numbers show that even two decades from now the biggest chunk of the cars we are running will be the existing internal combustion engines, the traditional cars. But electric cars will grow, especially in some regions. For example, in Europe there is a lot of incentive and subsidy for the electric cars. In China, lots of support for electric cars. And with the declining cost of batteries for electric cars, plus the very generous government subsidies in some countries, we see that the electric cars are increasing substantially.

Having said that, some people say, you say that electric cars will increase, but at the same time you think that there is a need for oil. How does it combine? It isn't following, Mr. Senator. The cars are not the biggest part of the oil demand growth. Oil demand growth today in the world is driven by trucks, jets, ships and, most importantly, the petrochemical industry. Even if there would be a lot of electric cars coming into markets, running in the streets of the world, we will still see that there is a need for new oil production.

Senator CASSIDY. Let me ask you this then.

Dr. BIROL. Of course.

Senator CASSIDY. There has been a move afoot to transition diesel vehicles, boats or trucks, to natural gas-powered vehicles. Do you see that impacting what you just said or will oil continue to dominate?

Dr. BIROL. Oil will continue to dominate, but as long as the cost of gas remains low or moderate we see, especially in the long-haul trucks, there's a big chance of substitution of oil by natural gas. And also, not only for trucks, but also for the ships.

Senator CASSIDY. Now, you say a big opportunity, but you have made specific projections regarding the percent of electric vehicles with a number. Have you done a similar analysis of what will be the rate of conversion of long-haul vehicles or barges or towboats to natural gas?

Dr. BIROL. Yeah, it was the expectation that they will increase at least three times compared to today, but still the big portion will be coming from the oil products.

Senator CASSIDY. Okay.

Dr. BIROL. Namely, diesel.

Senator CASSIDY. Now, I don't have it here in your testimony—you speak of the “sustained” model which I—or something such as that, with the word “sustained” in there—and I gather that would be compatible with a low-carbon mandate. The degree to which we achieve that, to what degree is that conversion of coal to natural gas or nuclear, and to what degree is that the deployment of renewables?

Dr. BIROL. If I can give a very few headline figures. We have different scenarios. One is with the current policies, where do we go? The other one, as you mentioned, sustainable, to keeping a close eye on the environment, especially climate change. In all of them natural gas does increase. Natural gas is a winner, increasing, it is a role in all of them. Renewables are growing very strongly in all of them, especially with the sustained one, especially for solar and wind.

And coal will be depending on whether or not we can use coal in a cleaner way, especially in the context of carbon capture and storage. This is, for me, an extremely critical technology and this is an area that I mentioned at our ministerial meeting, Secretary Perry and myself run a ministerial session on carbon capture and storage.

Senator CASSIDY. But let me ask, continuing on natural gas and renewables, in your current policy and the sustained policy, what is the relative growth of renewables and not only the relative growth, but by 2040 what is the percentage of the international energy mix that would be held by either the renewables or the natural gas?

Dr. BIROL. The share of natural gas will stay as it is now, about 20 percent, but the volume is going to increase.

In terms of renewable generation, it will grow also substantially, electricity coming mainly from solar and wind, but coal will be a significant loser unless we can make use of carbon capture and storage technologies.

One particular technology, again, is nuclear power. Nuclear power is a technology which can produce electricity without giving any emissions, but this will be also depending on the policies of the governments, whether or not they would like, to see nuclear play a more important role in the region.

Senator CASSIDY. Thank you.

I am over. I yield back.

The CHAIRMAN. Senator Smith.

Senator SMITH. Thank you, Madam Chair.

I am really so pleased to be here and be a part of this Committee and I must say, as a former resident of Alaska and actually a person who worked on the TransAlaska pipeline when it was first being constructed, this has always been a matter of great interest to me. So I am very pleased to be here.

Dr. Birol, it is very interesting to have a chance to visit with you and I am quite struck by your conversation about the transformation that we are seeing around the world in advancing renewables and also energy efficiency.

In Minnesota, my state, this has been a focus of our energy policy, a bipartisan focus of our energy policy and today we get about 21 percent of our energy from renewables and are well on our way to hitting our goal of 25 percent which, I think, could be even higher. And this means jobs for Minnesota, 57,000 clean-energy jobs in Minnesota. So I think a lot about the benefits of this kind of strategy.

You know, also, my business background has taught me that diversification contributes to risk management and to security. And so, I am quite interested to hear you talk a little bit more about how more affordable renewables and energy efficiency contributes to our overall energy security which is, sort of, the primary focus of the IEA.

Dr. BIROL. Thank you very much, Senator Smith.

Now, this is huge oil, gas, coal, renewable sources and it is very important that we make the most out of it in: A, a cost-effective manner; B, secure energy; and C, along in a sustainable manner. I think this is important, these three important parameters. We

see a growing chance of the U.S. making more use of renewable energies as their costs are coming down. And as Madam Chair mentioned, after the tax reform we see that the incentives, the support for the renewables, are still there.

One area that we need to, in my view, pay attention to is the efficiency. When we say U.S. will soon not need to import any single barrel of oil, this is for two reasons. One is the biggest access of the shale oil boom which is extremely important and it's a big success story of the U.S. Government, U.S. industry, the shale oil boom production will go. And the second is that, in my view, the CAFE standards. The CAFE standards in the United States keep the gasoline diesel consumption for cars and other vehicles at a certain level and save oil at home. If you didn't have the efficiency standards we would use more oil at home; therefore, the import needs will be higher.

Therefore, in addition to oil, gas, nuclear, I see that there is also a role for renewables and energy efficiency so we have a diverse and sustainable mix for the U.S. Government, for the U.S. energy sector, which should make the economy also very strong and resilient.

Senator SMITH. Thank you.

Let me just ask you. Where are we headed in terms of overall cost reductions for renewables?

Dr. BIROL. I think we expect that around the year 2020 most of the renewables in the world may not need any more subsidy. They can be competitive with the traditional sources of energy, unlike 10, 15 years ago. Ten, 15 years ago in order to compete with natural gas, with coal, with the others, they needed to get a lot of subsidies and sometime soon, in five years or so, we may see in many countries, most countries I should say, especially for solar and on-shore wind, we may not need subsidies. Maybe for offshore wind, we need a longer time horizon, but the main message is they are becoming cheaper and cheaper. They are becoming the mainstream fuel in many countries.

Senator SMITH. Thank you.

Dr. BIROL. Thank you.

Senator SMITH. Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Smith.

I have so many things.

[Laughter.]

Boy, this is fascinating this morning. I so thank you.

As you know, a couple years ago we reversed a 40-year policy that we had here in the United States that banned the export of oil. We were successful in lifting that in December 2015 and there was some speculation at the time that not much would change in terms of the volume of oil that is exported from the United States due to the price of oil, the need for infrastructure improvements and other global supply factors.

We have not necessarily seen that. We have not seen the price impacts. We have not seen the supply shortages that some claimed. Can you discuss how the export of U.S. oil has changed the world dynamic?

You referenced earlier in response to the question from Senator Cantwell, how with more LNG that the United States has put on

the global market, how that has impacted not only Europe, Russia, but can you speak to the role that we are playing in the world energy markets now that we are able to export?

Dr. BIROL. Of course, Madam Chair.

So December 2015 you took this, in my view, very good decision to—

The CHAIRMAN. Thank you.

Dr. BIROL. —lift the U.S. oil export ban because as we look at the global energy security, and I just say—very positive contribution to global energy security.

So it came and 2016 was a year that the U.S. oil industry had a difficult year because the low prices, low oil prices, for that year we have seen the exports were just under 600,000 barrels per day.

But 2017, last year, we saw an increase in the exports—it was about one million barrels per day most of the time; but certain weeks, about two million barrels per day—a significant contribution.

The important area here is that not only the size but the quality of the oil is very important that you are exporting. It is light and sweet, the quality which is very much in demand and, therefore, it can be used in many countries. Again, one of the major buyers is China today.

So looking at the years from now, 600,000, one million barrels per day in 2017, with the increasing U.S. oil production and increasing global oil markets, we expect U.S. crude oil exports will play an important role, even though we are not there compared to natural gas, LNG, but it makes also a significant and important contribution both in terms of size and in terms of good quality.

The CHAIRMAN. Interesting. When you think about where we have been historically with world conflict that comes about because of the virtual advantage that some nations have when it comes to energy resource, whether it is the Middle East, or other parts of the world.

Well, you have given us, kind of, a new view of where we are going with energy and energy worldwide, all that is coming on with regards to renewables. This means that countries that might not have fossil fuels at their disposal have other ways that they, too, can achieve their own level of energy production.

When we think about the potential hot spots for conflict that comes about over energy—we have had presentations here in this Committee, in the years that I have served on the Committee, and it always seems to have been focused around who has the capacity when it comes to those sources of fossil fuels.

Do you see this changing now that the broader world energy portfolio is a greater mix, whether it is what you are saying China is looking to with regards to nuclear, the price competitiveness and the advent as renewables are truly becoming more viable solutions?

How do you see things changing or am I over-simplifying things with my example and we still have the same, kind of, historical energy hot spots?

Dr. BIROL. An extremely important issue, Madam Chair, if I may say so.

Now there are two important changes happening in terms of geopolitics of energy. One of them is the coming of renewables—it is

important. It is for some countries more important than others. But if I may, the renewables we are using mainly for electricity generation; but for transportation, for home heating, for industry, we still use a lot of gas, natural gas; in some countries, coal; in some countries, electricity and others.

Therefore, the renewables changing the geopolitics of energy in a big way is not something I would agree. It makes a small dent, but it is not going to change the geopolitics of energy which is centered on oil and gas currently.

But the second change on the geopolitics of energy in the world is coming from the United States. This change, the geopolitics of energy, the U.S. coming as a major oil and gas country, being a major exporter, changes a lot of thinking, changes a lot of issues. Let me give you one example. Several years ago, the United States was importing a lot of oil from Middle East. Very soon, or perhaps nowadays, it is zero or close to zero. This is something very important. Another thing, U.S. is competing with Russia for European gas markets. The U.S. today is exporting gas to Poland, for example, whereas Russia—it has changed the dynamics significantly there.

And from a U.S. perspective, I am sure Secretary Tillerson, in the international negotiations with his counterparts, is sitting on his chair much more comfortably compared to his predecessors representing a country with a lot of oil and gas potential.

Having said that, if I had to pinpoint one vulnerability in our world in terms of oil and gas it is the following. Many countries in the Middle East and also some major Eastern European countries, their economies are single-product economies—oil, in some cases, gas. When the price of these commodities goes down or as we just discussed with Senator Cassidy here, in the very near future if the electric cars one day become a major, major part of transportation, they may seriously suffer their economies and they are not prepared for that.

Their entire economy and social life is based on oil revenues. This is a major vulnerability, especially today when the oil prices will be, we expect, more and more volatile and technology may have big surprises.

Therefore, at the International Energy Agency we are going to focus in our next energy outlook on the vulnerabilities of these countries and if you are Chair, Madam Chair, I will be very happy to come and report to you which countries, which vulnerabilities and what measures can be taken there.

But once again, geopolitics of energy has been redefined as a result of the developments in the United States in big times, but also in the introduction of renewable energies in some countries.

The CHAIRMAN. Very interesting. Thank you for that.
Senator Smith.

Senator SMITH. Thank you, Madam Chair.

Dr. Birol, I was really interested in the information in your report about how global energy usage we expect to increase by, I think it is 30 percent by 2040, which is the equivalent to adding another China and India to global demand. Also, I remember reading that yet there are still significant portions of the world where

people do not have access to electricity at all. So there is, sort of, this dramatic kind of dichotomy in terms of where people are.

I would like to hear your views on what countries can do to take advantage of this growth in demand, I mean, from a competitiveness perspective, position themselves and their economies. This relates, I think, to what you were just talking about. What countries can do to position themselves and their economies so that, literally, the trillions of dollars that are going to be invested in technology that, you know, the countries can be well-positioned to be competitive in that arena.

Dr. BIROL. Thank you very much.

So when we look at the investment trends in the next years to come, we see huge investment opportunities, especially in the electricity generation and transmission and distribution. Asia and sub-Saharan Africa are key areas for investment opportunities. And here, of course, as you implied, the U.S. companies can play a very important role, both in terms of building the power plants, providing capital and also providing leadership in those countries.

Having said that, those countries, especially in China, India, and African countries, they have their own energy policies, they have their own targets. And when I look at those policies, they are geared at having energy at the lowest possible cost, keeping an eye on the environment and also diversification of the energy, as you rightly mentioned. I think those countries would welcome the investment opportunities from the U.S. and elsewhere if the investments are in line with these three goals, namely the energy security, affordability of energy and at the same time the environmental production. And many U.S. companies are already working in those countries, but the demand for energy projects are huge across the world, huge infrastructure needs, especially in Asia and Africa.

Senator SMITH. And what about this question of research and technology and innovation? How do you see that in terms of how we can encourage that kind of innovation and research on new technologies?

Dr. BIROL. We made an analysis of how much the governments and the private sector is putting money in research and development in new technologies, clean technologies. To be honest with you, despite all of the discussions and rhetoric in the last five years, in real terms, there was almost no increase in the R&D in clean energy technologies across the world.

What surprised me also is when we're talking about, we think about the R&D, the research and developments in clean energy, I personally thought before the analysis the bulk of R&D is coming from the private sector and less from the governments, but our analysis just showed the opposite. The bulk of R&D for clean energy comes from the governments, 80 percent, and 20 percent coming from the private sector.

So there's a need for the private sector to be a bit more a part of the game to push the clean energy technologies and, therefore, energy efficiencies.

Senator SMITH. Great.

Dr. BIROL. Thank you.

Senator SMITH. Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Smith.

Let me just follow up on that just to make sure I understood. Your statement that the R&D in clean energy around the world—

Dr. BIROL. Around the world.

The CHAIRMAN. The vast majority of the funding, 80 percent, comes from government, 20 percent from industry?

Dr. BIROL. Exactly.

The CHAIRMAN. That is worldwide. What about here in the United States? Is that breakdown still about the same, about an 80/20, that we are not seeing the R&D in clean technology development?

Dr. BIROL. I need to come back to you for that, Madam Chair, but worldwide it was, for me, surprising as well.

The CHAIRMAN. Yes, that is.

Dr. BIROL. Because I thought when I read the interviews of the business leaders and so on, I thought the biggest part was coming from the industry and less from the public, but public was the main driver of the R&D in clean energy.

The CHAIRMAN. Well, that is very interesting. If you learn otherwise and particularly on the U.S. side, I would be curious to know about that because that is not what typically we would think.

You have referenced energy security many times here and we think about the security that comes with abundance of supply and how we can provide security that way. You have also referenced the electrification that we are seeing around the world.

You highlight in your testimony the increasing digitalization of power systems and, again, that can assist with levels of efficiency that, I think, is important. But I think we also recognize that with these opportunities it can bring challenges, certainly, when it comes to the issue of cybersecurity. You haven't really mentioned the role that plays with these interconnected energy systems. Can you just speak a little bit as to how you think digitalization provides levels of benefit but also vulnerabilities?

Dr. BIROL. In fact, it's an area that we just started to work, Madam Chair, very important because digitalization and energy, they are becoming more and more involved when we certainly made the report and Dave Turk, the former U.S. government official who recently joined our organization, was leading that work.

What we have seen is that digitalization provides a lot of benefits by increasing the efficiency of our systems. We save a lot of money, we save a lot of activity, and we need to build, for example, less power plants than otherwise would be needed as it is out of digitalization, that we are reducing the demand and improving our power systems. This is very good; this is something that will continue. It would help us to make, for example, the most out of the renewable energies as well.

I mentioned there is a mismatch between when the sun and wind are available and when the electricity demand is the highest. So digitalization will help to adjust this mismatch as well.

Now this is very good that our energy systems, our economic systems are becoming more and more digital, more and more interconnected to different devices, but this also raises the issue of cy-

bersecurity as the surface attack is becoming much bigger in terms of the unexpected assumptions.

So it is an area that we are working with our governments, how we can increase the resilience of our electricity systems in order to minimize such attacks. What kind of measures, regulatory and technical measures, need to be taken in order to minimize the undesired effects of digitalization in terms of making our systems more vulnerable?

This is a serious issue with the electrification and digitalization of our electric systems, Madam.

The CHAIRMAN. It is something that we focus a lot on here because as we work to enhance our systems and truly make them more efficient, make them more cost-competitive, you realize that you are also building in another level of vulnerability, if you will.

One more area of vulnerability that I want to bring up and I speak to a lot here in this Committee. Some years ago, when we were more reliant on other nations for our sources of oil, we talked about that vulnerability. And it was not only energy vulnerability, but vulnerability from a security perspective, national security perspective. Well, as you have pointed out, we are in a much better situation now, certainly, with regards to oil and natural gas and that undisputed position that you now refer to around the world coming from the United States.

But there is another area where I see a growing vulnerability on others and that is as it relates to our critical minerals and our resources, the resources that we need to help build out, whether it is wind turbines, whether it is the lithium for the lithium ion batteries. The reality that whether it is lithium, graphite, cobalt or nickel, these are what will allow us to help build out the battery, the storage capacity, that when we are talking about electrification moving to EV, electric vehicles, we have to have these sources.

I view that as a bottleneck, a potential bottleneck that will allow us to make this transition or move to these other areas that you have referenced—you referred to them as upheavals with what we are seeing with renewables. Can you speak a little bit about that aspect of vulnerability and where you see the direction or the trend here?

Dr. BIROL. Another excellent point, Madam Chair, if I may say so.

With the traditional fuel sources, oil and gas, the energy security is, more or less, well understood and mechanisms are there for oil and gas. We—IEA—have been working many, many years, and especially for natural gas, with the G7 meeting in Japan. We were asked by Prime Minister Abe to look after the gas security issue, which we are doing and electricity sector, I mention to you, very important, cybersecurity, we are working on that.

Yet, another security issue, indirectly, but also very important in terms of energy is the raw materials for the clean energy technologies. This goes from aluminum to copper, copper to lead, to lithium, manganese and it happens that, again, like the issue of the traditional sources several years ago, these are consumed at only a few number of countries. And again here, concentration of the resources, some of them are in Latin America, some American

countries here, Chile, Peru, Bolivia. But China happens to be a country with a lot of reserves in that context.

So, it is, when we're talking about the clean energy technologies, this is very good. This is good for the environment, good for the domestic production, but one has to, perhaps, go one step further to think about where those raw materials will come from and what kind of security mechanisms we can develop in order to, I guess, if some undesired problems arise, as the raw materials of those technologies are consumed in a few number of countries. It's very important.

The CHAIRMAN. Does IEA, not concentrate necessarily, but do you factor in these vulnerabilities as you look to your world forecasts?

Dr. BIROL. We mainly look at the vulnerabilities in terms of energy sources: oil, gas, electricity and renewables; but these are also an important area and it needs further attention.

The CHAIRMAN. Thank you. I appreciate that.

Senator Smith, further questions?

Senator SMITH. I do not have any further questions. I would just like to thank you very much.

Thank you very much, Dr. Birol, for your comments. This is quite interesting and I am very happy to be a part of this Committee.

The CHAIRMAN. Well, we are delighted that you are a part of the Committee.

I have one final question for you, Dr. Birol, before we conclude. And again, I thank you for your time this morning.

I have long maintained that nuclear in this country and part of our energy portfolio is significant, important, and we have seen the United States and our role with nuclear, in my view, slack off in recent years. We have one remaining construction project in nuclear, the Vogtle Plant in Georgia, but you have indicated in your comments here this morning that China is coming on in a quite considerable and a substantial way.

We have the traditional nuclear in the global marketplace. We also have the role of advanced nuclear. I think we are seeing some positive signs coming out recently in terms of these emerging technologies and how they might factor in to the energy marketplace. But can you just share with the Committee your view of how nuclear here in the United States factors in these out years, whether it be traditional nuclear or the advanced nuclear opportunities?

Dr. BIROL. Thank you very much, Madam Chair.

I think nuclear is a technology worldwide which can provide electricity, uninterrupted without emitting carbon emissions, but after Fukushima it became a challenge in many countries to be near nuclear power plants.

The challenge is not only there, the challenge is also in the financing part of the equation to be near nuclear power plants and even in some countries, like in the United States, where electricity demand is low, where the gas prices are low, where the renewables are growing, to find even getting electricity generation from nuclear is a big challenge, unless governments don't take any measures.

So for the new builds, in my view, it will be very difficult to go with the traditional nuclear power plants. Small, modular reactors

can provide the opportunity to address the project management risks and the financing problems. So this can be a solution.

If I go from, and I believe nuclear can play in the U.S. and in the countries where it is accepted, can play an important role for energy security and, also for the environmental issues, can make a positive contribution.

There is one more issue globally. As I said, as you also mentioned, in the U.S. we are building one, only, nuclear power plant. In Europe, the situation is similar, in Japan it is similar.

These countries were the main nuclear technology exporters until recently. But since they don't build any nuclear power plants they are forgetting how to build it and China and Russia are building a lot of nuclear power plants and they will not only build nuclear power plants at home, but they may well be the countries who are exporting the nuclear technology to other countries which is either important from not only from energy perspective but from other perspectives as well. So we have to look at the nuclear also, perhaps, from that angle as well that the established nuclear technology exporters such as U.S. and Europeans and others are facing a strong challenge from China and Russia for the other countries to build nuclear power plants.

The CHAIRMAN. When you think about where nuclear has dominated and, again, here in the United States and Europe, certainly in Japan, that reversal in a very, very short order, really, in terms of the energy spectrum worldwide. And now moving that over to China and Russia where we had not seen that much of a significant presence. It is really, kind of, an interesting phenomenon that it has moved as quickly and as, I would say, dramatically, as it has in terms of moving the energy portfolios around.

I wonder whether—and I am just talking off the top of my head here—but I wonder if an increased role and presence in Russia, in China particularly, will promote or spur the United States to renew its efforts within the nuclear space or whether we continue to cede and take a back seat.

It is not something that I think has been good. I greatly appreciate the role that nuclear plays in providing for not only a reliable power source, but a clean power source. And I regret that we are losing the skilled workforce, the level of leadership that we have played, not only from the production perspective, but how we then export the technologies and the smart people that come behind them.

Do you think that we change or with low natural gas prices, we just continue in the direction that we are?

Dr. BIROL. I think natural gas is, of course, very good. It is cheap. Renewables are also getting cheaper. But in my view having a diversification and nuclear, the position of nuclear in the U.S. is a strong one, to keep that position is wise policy. I wouldn't let it go.

The CHAIRMAN. No.

Dr. BIROL. But, of course, up to your government that they, yourself, to proceed a policy, but it will be regrettable, in my view. The United States has been one of the leaders of nuclear technology for years and years. Industry has been developed in this country in

1980's. To give it up, that position, may not be the best way, in my personal view.

The CHAIRMAN. Do you see Europe going back to more nuclear or is that an irreversible direction?

Dr. BIROL. I think in many countries, irreversible direction, but I think Japan is going back slowly to nuclear power, but the biggest development is coming from China and India. More than 90 percent of the new nuclear power plants coming in the future in the next years will come from China and India. And the Russians are building in Europe as well, several nuclear power plants. As by building a lot of nuclear power plants, they bring the costs down and making it cheaper, accessible to emerging countries.

So it is, in my view, an energy issue, but maybe not only.

The CHAIRMAN. One last question.

I said that my last one was going to be nuclear, but you prompted another and that is in regards to India.

Dr. BIROL. Yes.

The CHAIRMAN. You have focused a lot of your comments today on the role that China is playing in the world energy markets. Will India move more toward natural gas, toward coal, toward nuclear? Where do you see their energy portfolio?

Dr. BIROL. I think India chooses a policy which is all-of-the-technologies type of policy, and they are pushing, especially, natural gas strongly and, once again, to replace coal. But coal is also growing because in India, Senator Smith mentioned, people having no access to electricity in India, almost 200 million people have no access to electricity. They have to build some power plants from coal, but also more and more natural gas, renewable energy and nuclear. They are pushing in all fronts.

And to be very frank, the Modi government is pursuing an energy policy which is very good for their people because in a very short period of time, almost 11 years, they are bringing electricity to about 500 million people. It's a big, big, big achievement. And they are using gas. They are using coal. They are using renewables. All of those technologies, much more diverse and I expect the share of gas will increase significantly in India in the next years to come.

The CHAIRMAN. Well, very interesting. I will look forward to learning more from this report that you referenced earlier that will focus on those nations that perhaps have greater vulnerabilities because they are more reliant on a single energy resource, either for production or for their consumption and what that means.

It is interesting to hear that with India it truly is one of those all-of-the-above approaches to energy.

Dr. BIROL. Exactly.

The CHAIRMAN. I truly appreciate what you have shared with the Committee. It is always good, it is very important for us to understand what is happening with the global energy and the trends out there.

As one who has been a strong proponent of U.S. energy production, certainly within oil and gas, it makes me feel pretty good, actually, to hear you say that of the four upheavals that you have referenced, the first one is the U.S. being a leader in oil and gas production.

As I say, just in the few years that I have been here in the Senate and serving on this Committee, we have gone from a perspective of discussion about LNG import terminals to now export terminals, to a vulnerability and a reliance for our oil on countries that we do not like and they do not like us and now we are truly in the driver's seat. So that is significant.

But I think it also is very important for this Committee to hear very clearly the other areas that you have identified: the cost of renewables are moving quickly, and the direction that is being taken and the advances in solar and wind, the fact that they are getting to that point where they can stand on their own and be cost-competitive, that factors in mightily in terms of the direction that we move from a policy perspective.

And paying attention to what is happening in the world, the leadership of China. It has been very easy for us to say that China is the big polluter out there, but when they are advancing policies that are really keyed in on cleaner energy and energy sources and whether that is, again, importing LNG that may come from a place like Alaska or from elsewhere, but to recognize their leadership in nuclear. And then also, your fourth point about the share of electricity growing faster than the other sectors and the implications that portends.

So a lot to think about as we begin the new year, but thank you for your insight, for your guidance. We look forward to learning more from you about these very important geopolitical issues in the energy space. You have been most helpful. You have been generous with your time. We wish you safe travels back when you return to France.

Thank you very much.

Dr. BIROL. Thank you very much, Madam Chair.

The CHAIRMAN. Thank you.

With that, the Committee stands adjourned.

[Whereupon, at 11:40 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

**U.S. Senate Committee on Energy and Natural Resources
January 16, 2018 Hearing: *The Domestic and Global Energy
Outlook from the Perspective of the International Energy Agency*
Questions for the Record Submitted to Dr. Fatih Birol**

Questions from Chairman Lisa Murkowski

Question 1: Dr. Birol, you referenced that around the world 80 percent of research and development in clean energy/technology comes from government funding while 20 percent comes from private sector. Is the United States consistent with the global percentage split? Do you foresee private investment in these technologies increasing in the coming years both in the US and around the world?

Answer 1:

The IEA is the leading source of data on government energy R&D budgets. The data show annual declines since 2012, reaching around USD 17 billion in 2016, with over 70% directed to clean energy technologies. Data for the world's other large economies and the private sector is more challenging to acquire, and the IEA has compiled information from publicly available sources. This information shows that disclosed R&D spending of private companies in energy-related sectors has not grown since 2012, and in the highest-spending energy sector, oil and gas, it has actually fallen substantially since 2014.

Based on this published data, we find that federal spending in the US accounts for around 40% of energy R&D (including early stage venture capital) and around 70% of R&D specifically associated with clean energy technologies in particular. However, as the private sector data does not include such "non-energy" topics as automotive drivetrains and buildings energy efficiency, nor spending of non-listed companies, the total public share is likely to be somewhat overestimated by these results. The following implications appear robust nonetheless: the public share of clean energy research in the US is higher than that for all other types of energy research; and the private sector share of energy research is higher in the US than in most other major economies.

Question 2: You observed that "when we look to the future, we see that the cost of solar and wind will continue to decline, and they are going to compete very soon, without any subsidies, with the traditional sources of electricity." You also noted that a principal driver of solar deployment in countries such as China and India was not climate change but low cost. Please elaborate. Also, for the purpose of your observation about the cost of solar and wind generation in reference to traditional sources of electricity, over what time horizon do you see the change occurring?

Answer 2:

The cost of solar PV and wind has declined over the last five years driven by strong policy support, technology improvement and, more recently, by increased competition through auctions. Recent contract prices show that large-scale solar PV and onshore wind projects can be contracted at USD 30-50/MWh in countries with good resource availability and competitive auctions. The competitiveness of renewables in a given country depends on a number of factors,

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including current and expected prices of fossil fuels and the pricing of carbon and other externalities as well as costs associated with system integration of renewables. In an increasing number of countries, especially in Latin America, where fossil fuel prices are relatively high and long term contracts are attached to competitive auctions, new wind and solar projects are competitive with fossil fuel alternatives without subsidies already.

The main driver for renewable expansion in India and China has not been climate change mitigation but rather the fight against air pollution and improving energy diversification. More recently, the massive progress of cost reduction and prospect of wind and solar competitiveness is becoming a driver itself for new deployment. Just a few years ago, the main priority in India was to use cheap coal to support economic development. Today, this narrative has dramatically changed in favour of solar PV and wind. In recent energy auctions, some solar PV developers won contracts with prices comparable to coal tariffs in some Indian states. In addition, electricity generation from new solar PV and land-based wind plants is already cheaper compared to new combined-cycle gas turbines (CCGT) plants. It is expected that solar PV will be fully competitive with new coal generation in India by 2025. In China, falling costs will help the average solar PV project to be cheaper than both new and existing CCGT plants around 2020 while widespread competitiveness with new coal plants is seen after 2025.

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Questions from Ranking Member Maria Cantwell

Question 1: In your testimony, you mention the digitalization of the energy sector and risks such as cyber-attacks.

- How does the increasing digitalization of the energy sector increase the risks of cyber-attacks?
- How does the increased risk of cyberattacks affect our energy security?

Answer 1:

Digitalization brings many benefits, but it also opens the door to increasing risks for energy security, both from natural hazards such as geomagnetic storms and from unintended cyber incidents and intentional cyber-attacks. The further decentralisation and digitalization of energy will connect millions of new small-scale prosumers (consumers who buy and produce at least part of the consumed energy themselves) and billions of devices into the electricity system, where a single compromised device, or a generic flaw shared by thousands of devices from the same manufacturer, could be a weak point for the whole system.

Moreover, digital technologies used in centralised energy systems are also changing. The trend towards newer open-protocol industry standards, more automation and a shift to cloud computing might have a higher general level of security, but lose the protection previously provided by specialised, proprietary or vendor-specific software.

The attack surface is thus changing and vastly expanding. But also traditional energy systems, such as oil or natural gas production and processing facilities, are subject to constant probing and breach efforts by malevolent actors. An example from 2017 is the Triton/Trisis malware causing the shutdown of an oil processing facility in the Middle East.

Question 2: According to IEA's most recent market report, energy efficiency is saving households across the world 10 to 30 percent of their annual spending, with the most savings occurring in developed countries with longer histories of energy policies and higher costs of energy. Yet you discuss a notable slowdown in the implementation of new energy efficiency policies by governments around the globe in 2016.

- Did this continue in 2017?
- What do you see as the risk if governments are stagnant in their energy efficiency policies?
- What is the risk to consumers and businesses?

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- What do you see as the main reason why governments are stagnant in their energy efficiency policies?
- What do you see as the biggest needs for policy modernization?
- What are the most energy intensive areas of energy use NOT covered by efficiency codes and standards?

Answer 2:

Initial estimates suggest that the 2016 slow rate of implementation of new energy efficiency policies around the world continued in 2017. Stagnant efficiency policies will gradually reduce the economic savings being made by households and businesses. The benefits currently being enjoyed by consumers from improvements in energy efficiency are in large part owing to the efficiency policies implemented over the last decade or more, particularly in the United States where there is a long track record of strong policies over several decades.

The stagnation in energy efficiency policy implementation is driven by lower energy prices, leading to lower policy prioritization. Also the focus of the policy debate on long term outcomes leads to less of a focus on short term implementation issues. The greatest need for policy modernization is to see efficiency approached in a broad and integrated way, recognizing that a portfolio of policy measures is required to achieve efficiency gains, and that harmonization with other aspects of energy policy, such as renewables, is also required.

Amongst energy end-uses, heavy duty vehicles (trucks) have the lowest global coverage, with 16% of the global fleet having mandatory efficiency standards in place. Only Canada, China, Japan and the United States have standards in force, while India's new truck standards will come into effect in April 2018. With the exceptions of refrigerators and freezers, mandatory energy performance standards for appliances are also low but expanding.

Question 3: In a recent IEA report, it shows that fossil fuels subsidies have been slowly declining but still exceed estimated government support for renewable energy, which is a roadblock to a cleaner and more efficient energy future.

- What is the IEA doing and what can individual countries do to continue to remove subsidies for fossil fuels?

Answer 3:

The IEA is a strong supporter of international efforts to phase out inefficient fossil-fuel subsidies. A main avenue has been the World Energy Outlook (WEO), which has consistently

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been shining a spotlight on this issue with its annual estimate of the value of global fossil fuel consumption subsidies and related analysis on efforts to remove them. The IEA has also provided specific analysis and advice to bodies such as the G20 and APEC, including participation in voluntary peer reviews of participating economies to deepen understanding of the challenges confronting reform efforts and how these can be overcome.

Such subsidies are often justified by the wish to achieve particular political, economic and social objectives, for example to reduce energy poverty or to distribute wealth stemming from the exploitation of natural resources. However, in practice, fossil fuel subsidies are often not well-targeted, disproportionately benefiting wealthier segments of the population that consume more of the subsidized products. There are many best practices accumulated in the world, which suggests that well-planned, carefully implemented reforms can bring strong dividends. These include establishing a transparent pricing formula that reflects full cost of fuels, managing impacts for vulnerable groups, and communicating at all levels to ensure the public understanding of the reforms. According to the WEO, the value of fossil fuel consumption subsidy was \$260 billion in 2016; this figure has declined significantly in recent years, in part due to the lower oil price since 2014 but also due to pricing reforms in a range of countries including Indonesia, Malaysia, Mexico and many countries in the Middle East.

Question 4: The World Energy Outlook clearly states that, “securing clear climate benefits from gas use depends on credible action to minimize leaks of methane.” IEA analysis suggest that 40-50% of methane emissions can be mitigated at no net cost.

- What policy options and industry actions can take place to minimize methane emissions and leaks while also providing value back to companies and consumers?

Answer 4:

There are an increasing number of voluntary and regulatory efforts to tackle methane emissions from the oil and gas sector. Yet worldwide implementation of the abatement measures that, according to the analysis in the World Energy Outlook (WEO), have positive net present values would require a step-change in ambition as few countries outside North America have specific methane emissions mitigation frameworks in place.

To tackle the issue, policy-makers and industry need ultimately to accomplish two goals: measure and abate. Measurement is critical to assess the efficacy of policy actions and to assure the public of effective implementation; abatement is critical to reduce emission levels. The technologies that can reduce methane emissions are well documented, well understood and, for the most part, widely available. While a large portion of emissions can be abated using technologies and actions that would pay for themselves through the methane saved and sold, implementing abatement is often the real challenge.

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There is no single explanation for why these measures have not already been widely adopted, and reasons vary from country-to-country. Possible causes include a lack of awareness of the level of emissions or the cost-effectiveness of abatement, competition for capital within companies with a variety of investment opportunities, the measures not having sufficiently quick payback periods to satisfy companies, and the possibility of split incentives (where the owner of the equipment does not directly benefit from reducing leaks, or the owner of the gas does not see its full value).

Key policy and regulatory options to help overcome these hurdles include: setting an overall goal for emissions reductions; encouraging and supporting operators to quantify emission levels and ensuring that these are reported publicly; fostering collaboration and innovation across the industry to help find new technologies that can provide reliable measurement of emissions at low cost; establishing a body to be charged with oversight or enforcement; and pursuing efforts to help changing views in the industry on methane emissions and to help mobilizing the financing necessary to achieve emissions reductions.

Question 5: In your testimony, you discuss that oil use to produce petrochemicals is the largest source of growth in oil demand.

- What additional policies or initiatives are needed to help curb the growth of oil to produce petrochemicals?

Answer 5:

According to the World Energy Outlook (WEO), the use of oil in the petrochemicals sector is the main source of growth in oil demand between now and 2040 – both in our central scenario (the New Policies Scenario) and in a scenario that reaches internationally agreed goals on environment and energy access (the Sustainable Development Scenario). There are various policies and initiatives that can act to curb the projected growth, primarily by improving the efficiency of material use. This can be done by incentivizing technology innovation, in particular through the development of lightweight, long-lasting and high-performance materials, regulating the inefficient use of plastic materials and creating an environment more conducive to recycling and reusing materials. We estimate that improving material efficiency can contribute to reducing global oil demand for plastics production by around 10% in 2040. The use of bio-based feedstock also offers a potential alternative to oil demand, but this would require technological improvements to close the cost gap with conventional production technologies. The IEA will be producing specific additional analysis on this issue in 2018 with a report on the future of chemicals.

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Questions from Senator Joe Manchin III

Question 1: Dr. Birol, in the International Energy Agency's World Energy Outlook, your agency notes that "coal-fired power generation capacity has grown by nearly 900 gigawatts" since 2000. Net additions to 2040 are projected at about 400 GW. Coal is an abundant resource in West Virginia, the United States and globally. The WEO concludes that, without large-scale deployment of carbon capture and storage, global consumption of coal will become flat in the coming decades. Yet, coal continues to be a reliable, affordable and abundant energy resource that the U.S. as well as China and India continue to rely on. I have several questions with respect to these conclusions.

Do you believe that the additions of coal-fired generation since 2000 have added to the reliability and resilience of our electric grid here in the U.S. and to others around the world?

Answer 1:

The situations in the U.S. and China, which is the country where most of global coal power generation capacity has been added since 2000, are very different. In China, electricity generation has gone from less than 1400 Terawatt hours (TWh) in 2000 to over 6000 TWh in 2016. Coal, representing around 70 percent of the electricity generation, is the cornerstone of power generation in China. The strong increase in power consumption in the country came in parallel to the buildup of coal power generation capacity. In the U.S., by contrast, production of electricity grew slowly from 4026 TWh in 2000 to 4297 TWh in 2016. During that time coal's share of generation fell from 53 percent to 31 percent, with natural gas (thanks to the shale gas revolution) increasing its share from 15 to over 34 percent and renewables growing from 9 to 15 percent. Nuclear power remained steady at 20 percent.

Generally speaking, generation capacity, especially if this is firm capacity, increases reliability and resilience of the grid. In order to determine how large a contribution a particular plant makes to the reliability of a particular power system a detailed analysis is needed to identify potential strengths and weaknesses of the grid and how much each plant, whether gas, coal, nuclear or other technology, contributes to ensure reliability.

Question 2: What is your understanding of efforts to commercialize CCUS and other technologies – both domestically and globally? Are China and India – the world's largest consumer of coal – investing in these technologies? Do you agree the U.S. can be a leader in the commercialization of this technology?

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Answer 2:

Successful projects in the US and elsewhere have demonstrated the technological viability of CCUS, yet it is currently only applied to a tiny fraction of facilities globally, well short of the deployment in the WEO Sustainable Development Scenario. Building the business case for investment in CCUS will be the key to the next wave of projects. In many places, doing so will require government support at least in the short to medium term.

The US has been a leader in CCUS for several decades. There are 17 full-scale CCUS projects globally, half of them in the US. The opportunity to use CO₂ to enhance oil recovery from aging fields in the United States has created a value for CO₂, helping build the case for investing in CO₂ capture. In the United States, CO₂ is being captured from gas processing facilities, refineries, hydrogen production, bio-ethanol production and a coal fired power plant. As well as EOR, CO₂ is being stored in dedicated underground formations. The United States can, and should, continue its leadership in the area.

China has invested significantly in developing CCUS technologies, and currently has its first full scale project under construction. CCUS features heavily in the Chinese Government energy sector planning to reduce emissions from its coal to chemicals facilities and coal fired power plants.

India is still assessing the potential role CCUS can play in reducing emissions from its coal fleet. The rollout of CCUS may be constrained by the availability of suitable sites for dedicated storage or enhanced oil recovery (EOR).

CCUS is a priority area for the International Energy Agency. The feedback received during the CCUS Summit held during the IEA Ministerial meeting in November 2017 that was co-chaired by U.S. Secretary of Energy Perry and me encouraged the IEA to further increase the profile of CCUS and bring it to high-level meetings and events in 2018 and 2019. We will also undertake analysis that supports the commercialisation of CCUS and facilitates investment, including business and policy models and the role of CO₂ utilisation. We will also foster partnerships amongst governments and industry to enhance the role of CCUS.

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Question 3: What are nations like China and India doing to make their coal-fired plants cleaner and more efficient?

Answer 3:

China and India are two countries where coal is the most abundant fossil fuel by far and, therefore, their power systems are largely based on coal generation. In China, where reducing air pollution is one of the policy priorities, emissions standards for coal power plants have been tightened since the 1990s. In addition, power produced by plants equipped with scrubbers to reduce emissions receives a higher tariff. At the same time, the most heavily polluting coal plants have been closed. The regulatory and incentive schemes have resulted in a declining emission rate for years. Likewise, plant efficiency has increased by incorporating more Ultra-supercritical plants and closing less efficient plants (usually also generating the most pollutants). The combination of these policies is driving China towards a high efficiency and low emission coal power fleet. India is lagging behind in both aspects, but the government is also pushing to reduce emissions from coal power plants and increase efficiency.

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Questions from Senator Tammy Duckworth

Question 1: The World Energy Outlook indicates that the future of nuclear energy and carbon, capture and storage (CCS) technologies is uncertain. However, the International Energy Agency's (IEA) Sustainable Development Scenario relies heavily on both technologies to achieve the Sustainable Development Goals related to energy.

In your opinion, can the United States reasonably expect to achieve the objectives laid out by the Paris Agreement on climate change without nuclear energy and CCS?

Answer 1:

In its main scenario, the World Energy Outlook (WEO) gives an indication of where current policies and announced plans would likely lead the energy sector. Under that scenario, nuclear investment increases globally. Even in the United States, we see current trends leading to a stable nuclear fleet in 2040, only slightly smaller than today, although low wholesale electricity prices are presenting financial challenges for existing and new nuclear plants. For CCS, we estimate that current and announced policies and trends are not likely to see the technology grow to commercial scale by 2040.

Our Sustainable Development Scenario sets out a pathway for how the world could achieve the energy-related Sustainable Development Goals, and indicates what kinds of policy evolution would be required to get there in the most economical fashion. To achieve the objectives of the Paris Agreement, we anticipate an increased role for both nuclear and CCS globally, including in the US. The US nuclear fleet would be about 20% larger under this scenario in 2040 than under our main scenario. Under this scenario we anticipate that part of the remaining US fleet of coal- and gas-fired power plants would be equipped with CCS, partly driven by expanded support policies and R&D.

Without nuclear energy and CCS, the US could still reasonably pursue the objectives laid out in the Paris Agreement, but may face additional challenges as a result. The United States has a diverse set of abundant energy resources, including coal, oil and gas, but also renewable energy. A recent study indicates that the technical potential for wind power and solar power are each several times larger than current US electricity demand. Renewables are also becoming increasingly competitive with conventional fossil-fueled power plants on a cost basis; in the main scenario of the WEO, onshore wind and solar PV are projected to become the cheapest new sources of electricity in the US by 2030.

Our scenario indicates what we estimate to be the most cost-effective way to achieve climate goals and maintain competitiveness in a modernizing global economy, but it is not the only pathway. The US could potentially achieve a pathway consistent with the Paris Agreement under existing nuclear trends and without expanding CCS. However, this pathway would likely be more expensive and would face further challenges. Fuel diversity contributes to the security of

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electricity supply, providing a measure of protection from unforeseen market and environmental factors. A wider set of technologies also accommodates regional variations within the US.

Question 2: Illinois has more nuclear reactors than any other state, and is proud to be the home to two of our nation's crown jewels of cutting edge nuclear research, Argonne National Laboratory and Fermi National Accelerator Laboratory.

Congress must prioritize advancing policies that ensure nuclear energy remains a safe and affordable component of a diverse and comprehensive clean energy strategy. The nuclear industry continues to be challenged with high capital costs. During your hearing, you shared that small modular reactors (SMRs) could help the industry address this issue.

Please describe the specific policies required to promote the construction of SMRs, and whether implementing such initiatives could lead to economic growth and the creation of new American manufacturing jobs.

Answer 2:

Small modular reactors (SMRs) are at an early stage of technology development, and this should be reflected in the types of policies to promote the technology. In 2017, the first and only proposed SMR design was submitted for approval by the US Nuclear Regulatory Commission. The likelihood of the technology's ultimate success could be enhanced by funding research and development with the aim to expand the number of proposed designs, continuing the long history of developing new technologies in the US. As the technology continues to progress, supporting innovation through financial contributions for the first-of-a-kind projects would provide a critical bridge to the eventual commercialisation of SMR technology.

In the case where SMR technology becomes commercial, in terms of available designs, the supply chain to support deployment and comparable costs to other technologies, policies should evolve to support the technology and capitalise on potential opportunities. Technology-neutral support mechanisms for clean energy, such as competitive auction schemes or clean energy portfolio standards, would provide a level playing field for SMRs and support the cost-effective deployment of the technology alongside other clean energy technologies. Action to develop and deploy SMRs could position the US as a leader in the technology, providing opportunities to establish domestic manufacturing and supply chains. Technology-specific design, engineering and operational jobs would be created in the process. Beyond the domestic market, development of SMR technology could present export opportunities to foreign markets.

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Question 3: In your testimony, you indicated there is a need to prioritize cybersecurity as the electricity sector becomes increasingly digitalized. What do you believe are the highest cyber security vulnerabilities in the sector and what specific policies should Congress consider to bolster the industry's cyber defenses, pre-emptively mitigate risk and improve our response capabilities to successful cyber-attacks?

Answer 3:

Fully preventing cyber-attacks is impossible. It is therefore important to mitigate their impact by good preparedness and building resilience into energy systems, specifically, and critical infrastructure, in general. Systems need to be designed in a way to be able to resist, absorb an attack or an incident, maintain minimum critical function and quickly recover to original service. Capacity to adapt to new risks and threats is critical.

Building system-wide resilience depends on all actors and stakeholders first being aware of the risks. Governments have a key role to play in raising awareness and sharing best practices in this regard. International cooperation is particularly important due to the global and instant nature of the internet. An attack against a particular asset can rapidly spread across the world; an attack against a particular company can be launched against this company's assets in every country the company operates. Cyber-attacks can target personnel, infrastructure and processes. There is therefore a great need to protect the integrity and confidentiality of information and to identify trustable sources and authorised recipients in a network.

Promoting proper cyber hygiene, or a basic set of precautions and monitoring, is key. Reinforcing a security-conscious culture at all levels of users such as keeping software up to date or not sharing access rights can greatly increase overall security. A great majority of attacks or security breaches could be avoided if users followed these rules.

Research and development will play an important role in increasing security and reducing risk. Security objectives and standards will need to be incorporated as a core part of the research and design process, and not added ex-post as is the case notably in many systems that have already been in place for some time. The United States is already a global leader in many of these critical resilience elements, running state-of-the-art exercises together with other North-American partners and maintaining a high level of involvement in groups such as the G7, NATO, the IEA and OCED (on issues beyond energy). The United States is also at the forefront of security research conducted in its national laboratories.

